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Application and Exploration of Image Processing Technology in Ancient Books Protection and Design

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***Abstract*—Background: With the popularization of digital technology, its application in the field of literature and museums is becoming more and more extensive, especially in the restoration of ancient books. Digital restoration technology is gradually replacing traditional manual restoration and becoming mainstream. In order to improve the quality and efficiency of ancient book restoration work, the use of digital technology has become an inevitable trend. This study aims to explore the application of image processing technology in the conservation of ancient books and its value. Purpose: This study aims to clarify the core role of image processing technology in the conservation of ancient books, to construct a research system for designing the conservation of ancient books based on image processing, and to evaluate its effect through practical cases. The main tasks include sorting out the current status of application, constructing theoretical framework, practical exploration and effect assessment. Methods: Through high-precision scanning and digital processing, such as enhancement, denouncing, binarization, layout analysis, text recognition, etc., ancient books are transformed into digital images to preserve and deeply analyze the information of ancient books. These operations can improve the image quality, readability and accessibility of ancient books. Conclusion: Exploring the conservation of ancient books and their design research from the perspective of image processing can help to effectively protect and pass on cultural heritage and promote cultural inheritance and development. It is crucial to promote the standardization, scientificization and efficiency of ancient book protection. In the future, we should continue to strengthen the research and application of image processing technology to contribute to the cause of ancient book protection.**

Keywords- image processing; antiquarian book conservation; image enhancement; design study;

I. INTRODUCTION

As a valuable part of the cultural heritage of mankind, the conservation and restoration of ancient books is of paramount importance. As witnesses to history and carriers of culture, ancient books carry the wisdom of their predecessors and the important mission of future generations to explore the past and understand tradition. Each ancient book is a microcosm of history, reflecting the society, humanity and aesthetics of the time. By reading ancient books, we can gain a deeper understanding of the life, customs, beliefs and values of ancient societies.

Image processing technology plays a key role in the conservation of ancient books. Through high-precision scanning and digitization, ancient books can be permanently preserved and prevented from loss. In addition, image processing technology can decontaminate, enhance and restore ancient books to make their contents more legible and readable, facilitating research and utilization. We expect to clarify the core role of image processing technology in the conservation of ancient books, and to promote the standardization, scientificization and efficiency of the conservation of ancient books.

By exploring the contents of ancient books, we can gain a deeper understanding of all aspects of ancient society and provide support for academic research. In the design research of ancient book protection, the characteristics and application need of image processing technology should be fully considered. On the one hand, research on image processing algorithms should be strengthened to improve accuracy and efficiency; on the other hand, it should be combined with the practice of ancient book protection to promote innovation and development.

II. CONCEPT OF IMAGE ENHANCEMENT TECHNIQUES

Image enhancement is one of the relatively simple but most artistic areas of digital image processing, the purpose of enhancement is to eliminate noise, reveal those details that have been blurred or simply highlight the emphasized part. Image enhancement techniques can be used to improve the contrast, brightness and clarity of antique book images, making them easier to read and understand. Denoising technology can effectively remove the noise and interference in the images of ancient books and improve the signal-to-noise ratio of the images. Binarization technology can transform the antique book image into black and white binary image, so as to better highlight the text and layout information. Layout analysis technology can

automatically identify and analyze the layout of the ancient books, and extract various layout elements, such as text, images, tables, and so on. Text recognition technology, on the other hand, can automatically recognize and convert the text in ancient books into editable text format, which is convenient for subsequent processing and analysis.

When we are acquiring the content of ancient documents, there are often problems such as uneven illumination, significant noise, blurred character features and large amount of information due to the interference of the shooting environment. In order to improve the recognition accuracy, it is necessary to implement preprocessing of digital images of ancient Chinese characters before text recognition. The preprocessing algorithms highlighted in this chapter include: binarization algorithm, image enhancement algorithm and tilt correction algorithm, and the preprocessing of color images of ancient Chinese characters is practiced through Opencv tool. The experimental results show that the adopted image preprocessing algorithms can effectively eliminate the image background noise, retain the target feature information, and improve the speed of the recognition operation. Most of the existing ancient documents are isolated, the paper is fragile and fragile, and the pictures are yellowed and faded. Through digital conversion, the documents can be protected to the maximum extent and the direct contact with the originals can be reduced. However, in the implementation process, we found that text recognition in ancient documents faces two major difficulties:

A. Ancient literature varies in context.

Ancient documents, such as posters, books, and stone tablets, carry unique historical and cultural backgrounds, and their textual features vary significantly. Although it seems intuitive and feasible to train a specific classifier for each type of text, it is inefficient and impractical to do so. Therefore, designing a text classifier with strong generalization performance that can effectively ignore the noise of different textual backgrounds is a daunting challenge. This challenge requires us to explore a solution that can flexibly adapt to different text backgrounds and efficiently differentiate text contents based on an in-depth study of the characteristics of various types of documents [12].

B. Ancient documents are written in a variety of methods and script styles.

Ancient documents show remarkable diversity in writing methods and script styles. The evolution of Chinese characters has a long and varied history, the roots of which can be traced mainly to the hieroglyphics used to record events. Thus, pictographs are regarded as the cornerstone of the formation and development of the Chinese character system. As shown in Figure 1, Chinese characters have gone through a long and complex evolutionary process, eventually evolving into the simplified Chinese characters we use today. In view of this, it is undoubtedly a challenging task to construct a character database that can recognize various writing methods and styles of characters. Considering the limited number of existing early Chinese documents such as oracle bone inscriptions and jinwen, and the relatively low practicality of these documents due to the large background noise, this study focuses on the Regular Script and Running Script scripts, which are similar to the modern Chinese characters.

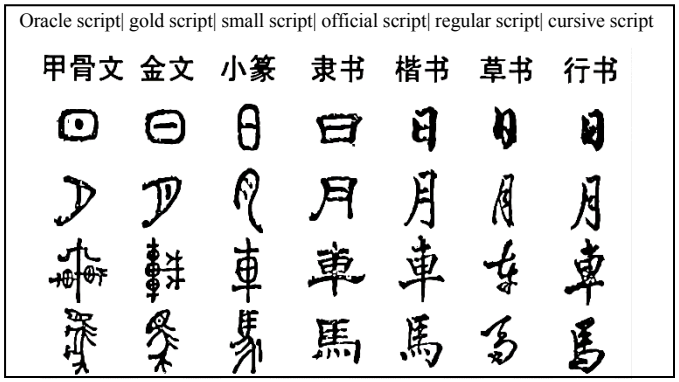

Fig. 1 Evolution of Chinese character images

III. BINARIZATION PROCESSING

A. Grayscale processing

Images in life can be divided into three main categories: color, grayscale and black and white. The representation of color images relies on a specific color space model; for example, a movie consists of successive frames of color images. Common color spaces include CMY (a three-color model based on subtractive color mixing), HSV (a model that combines saturation, hue, and lightness), and RGB (a model based on the primary colors of red, green, and blue). The color images of ancient Chinese characters are rich in color information data, which have relatively little influence on the image morphology. Therefore, during the gray scaling process, although some information in the image is lost, the brightness, which is crucial for computer recognition, is preserved. The luminance of a newly synthesized color depends on the sum of the luminance of its primary colors, while the hue depends on the mixing ratio of each color [1]. This processing provides a solid basis for subsequent image segmentation.

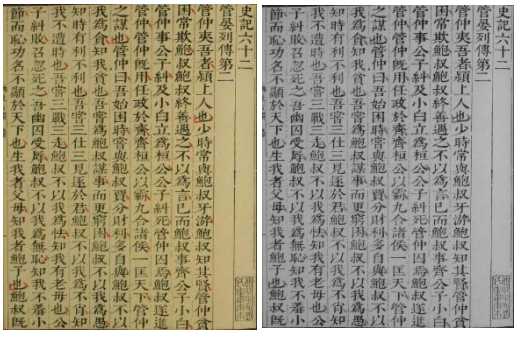

Fig. 2 Original image and grayscale plot

The paper adopts the method of weighted average to transform the color image of ancient Chinese characters into grayscale, which normalizes the color of the image of ancient Chinese characters and retains the brightness information of the characters of ancient Chinese characters, reduces the storage space of the grayscale image of ancient Chinese characters, and reduces the amount of data computation in the subsequent image processing and recognition, so as to improve the execution speed

of the program. Using the Opencv library function in Python, the processing effect is shown in Figure 2.

The mathematical formula is as follows, that is, the weighted value of the three channels in the color image is taken as the gray value:

$$Gray = 0.2989^{*}R + 0.5870^{*}G + 0.1140^{*}B \quad (1)$$

B. *Gaussian filtering to remove noise*

Gaussian filtering is the most direct and effective denoising method, and its application to discretized sliding window convolution utilizes a two-dimensional convolution transformed into two one-dimensional convolutions, thereby greatly reducing the speed of operations [2]. Image Gaussian filtering in the field of mathematics is a process of convolution from an image and a Gaussian kernel, in which the high number of two-dimensional Gaussian is formulated as follows:

$$H(x,y) = \frac{1}{2\pi\sigma^2} a^{-\frac{x^2+y^2}{2\sigma^2}} \quad (2)$$

Where: x and y denote the Euclidean distance between the current pixel point and the center pixel point; "σ" denotes the standard deviation.

In the two-dimensional dimension, when the image with $h \cdot w$ size is convolved with the convolution kernel of $s \cdot s$ size, the complexity is $h \cdot w \cdot s \cdot s$ .According to the two-dimensional Gaussian formula [3], the X-axis can be derived above the Y-axis, which is expressed by the lower formula. Using this feature, this paper uses two one-dimensional product kernels to replace the two-dimensional product kernel, first convolving the images along the X axis and then along the Y axis, optimizing the complexity to $h \cdot s \cdot w \cdot 2$, in order to reduce the computational amount, the processing effect is shown in Figure 3.

$$H(x,y) = \frac{1}{\sqrt{2\pi\sigma^2}} a^{-\frac{x^2}{2\sigma^2}} \cdot \frac{1}{\sqrt{2\pi\sigma^2}} a^{-\frac{y^2}{2\sigma^2}} = H(x) \cdot H(y) \quad (3)$$

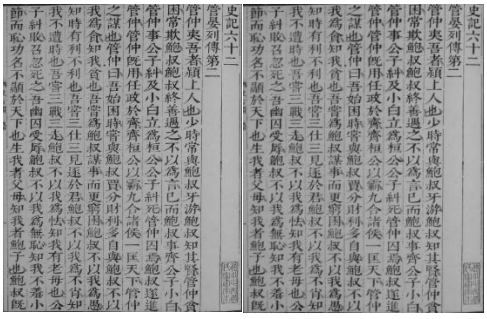

Fig. 3 Grayscale map and Gaussian filtered images

C. *Gray scale map and Gaussian filtered image*

Currently, most of the numerous image recognition methods take binary images as a starting point because binary images are simple to construct and their pixel values are limited to 0 or 1 [4]. When faced with the task of recognizing images of ancient Chinese characters, it is particularly crucial to process the images with a quadratic binarization algorithm. In essence, the binarization process is a thresholding operation on the image. Generally speaking, a high-quality binarized image needs to satisfy two core criteria: first, the strokes should maintain continuity; second, the image should retain effective character feature information. The specific processing effect is shown in Figure 4.

Fig. 4 Gaussian filtered image and binarized images

In this paper, using adaptive thresholding is a simple local thresholding method, and there are two implementations of adaptive thresholding in OpenCV, adaptive thresholding based on neighborhood gray average and adaptive thresholding based on Gaussian weighted sum [5]. Suppose the image point (x, y) at the pixel gray value of $f(x, y)$, the neighborhood size is $r \times r$, the set the offset value of C , point (x, y) threshold of $g(x, y)$, the neighborhood average method according to the gray mean of the pixel neighborhood to determine the pixel threshold, pixel neighborhood gray mean minus offset C is the threshold size, can be expressed as:

$$g(x,y) = \frac{1}{r \times r} \sum_{i=x-\frac{r}{2}}^{x+\frac{r}{2}} \sum_{j=y-\frac{r}{2}}^{y+\frac{r}{2}} f(i,j) - C \quad (4)$$

D. *P*erspective transformation

Ideally, photographs of antique books and other cultural relics should present a standard rectangular shape. However, in the actual shooting process, due to the possible angular deviation between the camera and the antique books, the obtained photographs have different sizes, lack of uniformity and different angles, as shown in Figure 5. According to the research of scholars at home and abroad, such deviations can be mainly attributed to three patterns: horizontal tilt, vertical tilt, and horizontal-vertical tilt at the same time. These deviations may cause certain troubles and challenges to the subsequent image processing, analysis and recognition. Therefore, when taking photos of ancient books and other cultural relics, the accuracy of the angle between the camera and the subject should be ensured as much as possible in order to obtain more standardized and reliable photo data [6].

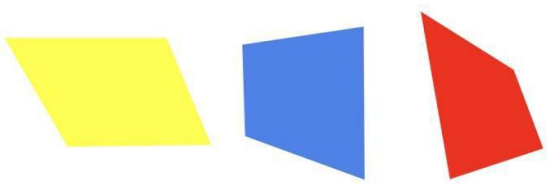

Fig. 5 Distorted images

E. *Image enhancement*

Image enhancement algorithm techniques aim to enhance the valid information in an image, highlighting features of interest and suppressing uninteresting parts in order to keep the overall target feature information reasonable while removing noise. Although this process may result in loss of some frames, it is necessary. Common image enhancement methods include gray value stretch conversion (e.g., linear stretch and discrete system stretch), bar adjustment, image sharpening, image filtering, and color image enhancement [7]. These methods can be categorized into routing enhancement and frequency domain enhancement. Routing enhancement methods traverse the gray levels of image pixels using specific vertices, while frequency domain enhancement methods are similar to the Fourier transform in data signals, where the image is transformed to the frequency domain and then a specific solution is executed for enhancement purposes [11].

Table I Comparison of Filter Principles

Filter type	Filtering Principle	filtering effect
Maximum filter	The maximum value of the gray value of the pixel in the filter window is used as the result of the filtering.	Reduces pepper noise by weakening dark areas adjacent to bright areas
Minimum filter	The minimum value of the gray value of the pixel in the filter window is used as the result of the filtering.	Weakening of bright areas adjacent to dark areas reduces salt grain noise

This paper draws on the optimization algorithm of maximum-minimum filtering and its computational method, while considering the simplicity of hardware configuration [8]. On this basis, this paper proposes to use CLAHE (Contrast Limited Adaptive Histogram Equalization) algorithm for image enhancement. Through in-depth theoretical analysis and combined with simulation experiments of Pycharm software, we use the maximum-minimum filtering method (As shown in figure 6) as well as the CLAHE algorithm to adjust the image more flexibly and carefully. This method can not only improve the processing effect of the image, but also shows a good application prospect.

- Max Filters Principle (Max Filters)

$$g_{max}(x,y) = max_{(s,t\in N(x,y))}[f(s,t)] \tag{5}$$

- Principle of Minimum Filter (Min Filter)

$$g_{min}(x,y) = min_{(s,t\in N(x,y))}[f(s,t)] \tag{6}$$

Fig. 6 Perspective transformed image and max-min filtered images

- Constrained Contrast Adaptive Histogram Equalization (CLAHE)

Histogram equalization is used to adjust the image contrast so that the output image grayscale histogram is evenly distributed [9]. However, the original method does not consider localization, which may lead to over-enhancement and information loss. To solve this problem, CLAHE (Constrained Contrast Adaptive Histogram Equalization) is used, which is an improvement of AHE (Adaptive Histogram Equalization) that enhances the character features, highlights the details and reduces the noise interference. CLAHE not only optimizes the histogram but also improves the adaptive histogram. By setting a threshold, cropping the gray levels that exceed the threshold, and distributing the exceeding portion evenly to each gray level, the result of the mapping function is smoothed. The operation formula is:

$$P(k) = \begin{cases} \mathrm{T_{max}}, & P(k) \geq T_{max} \\ \mathrm{P(k)}, & T_{min} \leq P(k) \leq T_{max} \\ \mathrm{T_{min}}, & 0 \leq P(k) \leq T_{min} \end{cases} \tag{7}$$

Where $P(k)$ is the value of the adaptive histogram of the image limit contrast. At present, consider the lower limit contrast threshold $T_L = 0$, and set the upper limit contrast threshold $P_{T(k)} \geq P(k)$. Development of the histogram equalization algorithm based on Eq. First, the statistical histogram was modified, and then the cumulative histogram of the image was obtained from the corrected statistical histogram. The gray value of the image can be redistributed by accumulating the histogram to obtain the balanced image, and a similar histogram is used to achieve this goal [10]. Of the corrected histograms are accumulated:

$$F_{T(k)} = \sum_{i=0}^{k} P_{T(k)}, \quad 0 \leq k \leq 255 \tag{8}$$

Where is the cumulative histogram of the image. The processing result graph is shown in Figure 7.

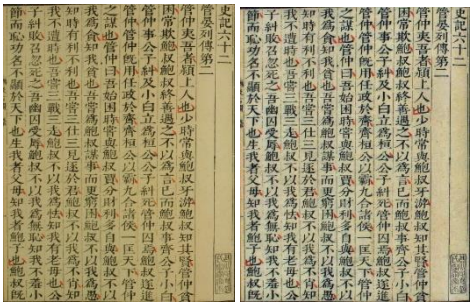

Fig. 7 Perspective-transformed image and contrast-limited adaptive histogram equalized images

V. CONCLUSIONS

Contrast-limited adaptive histogram equalization is an image processing technique designed to enhance the contrast of images with a small dynamic range. The process mainly relies on a gray level statistical histogram and a gray level cumulative histogram. Specifically, the gray level statistical histogram is used to show the distribution of the number of pixels at each different gray level in the image, while the gray level cumulative histogram reveals the number of pixels in the image whose gray level is

less than or equal to a particular value. By converting these histograms into a uniformly distributed form, the dynamic range of the pixel gray level values can be effectively increased, thereby enhancing the overall contrast of the image. As shown in Figure 8, this process has a significant effect on improving the visual effect of the image.

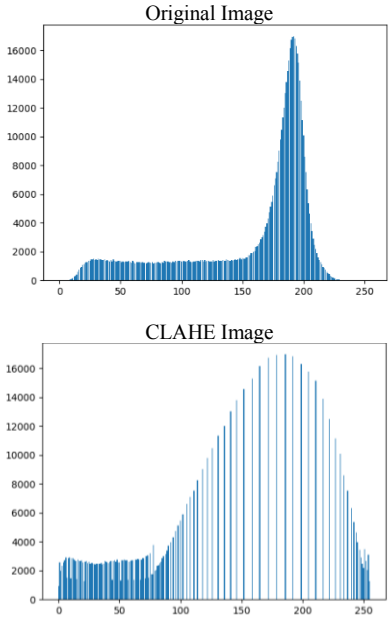

Fig. 8 Limiting Contrast Adaptive Histogram Equalization Histogram Before and After

In conclusion, the protection of ancient books based on image processing is of great significance for the protection and transmission of cultural heritage and the promotion of cultural inheritance. With the progress of technology, this kind of protection will become more and more popular and mature. Image enhancement and denoising technology can optimize the images of ancient books and make them easier to read. Binarization technology highlights text and layout information. Layout analysis technology automatically identifies and analyzes the layout of ancient books and extracts various elements. Text recognition technology converts the text of ancient books into editable text, enhancing readability and accessibility. The digitized ancient books are easy to store, transmit and share, promoting the dissemination and utilization of ancient books.

RESEARCH PERSPECTIVES

Image processing technology, as an important branch of today's science and technology, has been widely used and will continue to develop in the direction of greater intelligence and automation in the future. This process will be closely integrated with cutting-edge technologies such as artificial intelligence and machine learning, which will significantly improve the efficiency and accuracy of image recognition, and then play an indispensable role in a number of key areas such as intelligent surveillance and automatic driving. At the same time, multimodal fusion applications will become an important way to explore the diversity and richness of image information and continuously expand its application areas. To achieve this goal, optimizing the image processing process is particularly important. This includes, but is not limited to, enhancing preprocessing work, improving algorithm design, and making full use of advanced technologies such as cloud computing to improve overall efficiency and reliability.

Looking to the future, image processing technology is bound to become more sophisticated and efficient, opening up broader prospects and opportunities for social development and technological advancement. We look forward to more breakthroughs and innovations in this field to promote the continued prosperity and development of human society.

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